NATIONAL HARMFUL ALGAL BLOOM (HAB) FORECAST SYSTEM
GULF OF MAINE

Overview:

- Seasonal HAB prediction issued annually by the Woods Hole Oceanographic Institution (WHOI) and North Carolina State University (NCSU) as a press release prior to the onset of the HAB season (generally in March).

- Weekly model prediction and model/observation comparison issued beginning in April or sooner if there's an indication that the bloom season has started (e.g. detection of toxic shellfish, models indicate bloom initiation, etc.) until the bloom season has ended (typically through July). Operational need may be more frequent.

- Products distributed via e-mail to the WHOI managed Northeast PSP distribution list comprised of coastal resource managers, local, state and federal public health officials, academic and research institutions, and regional associations (see Recipients section for agency listing).

Status:

- Demonstration weekly model predictions for the Gulf of Maine issued since 2006;
- Demonstration seasonal HAB predictions issued for the Gulf of Maine since 2008;
- Transition to operations at NOAA's Center for Operational Oceanographic Products and Services and NOAA's National Centers for Environmental Prediction tentatively planned for FY13-14.
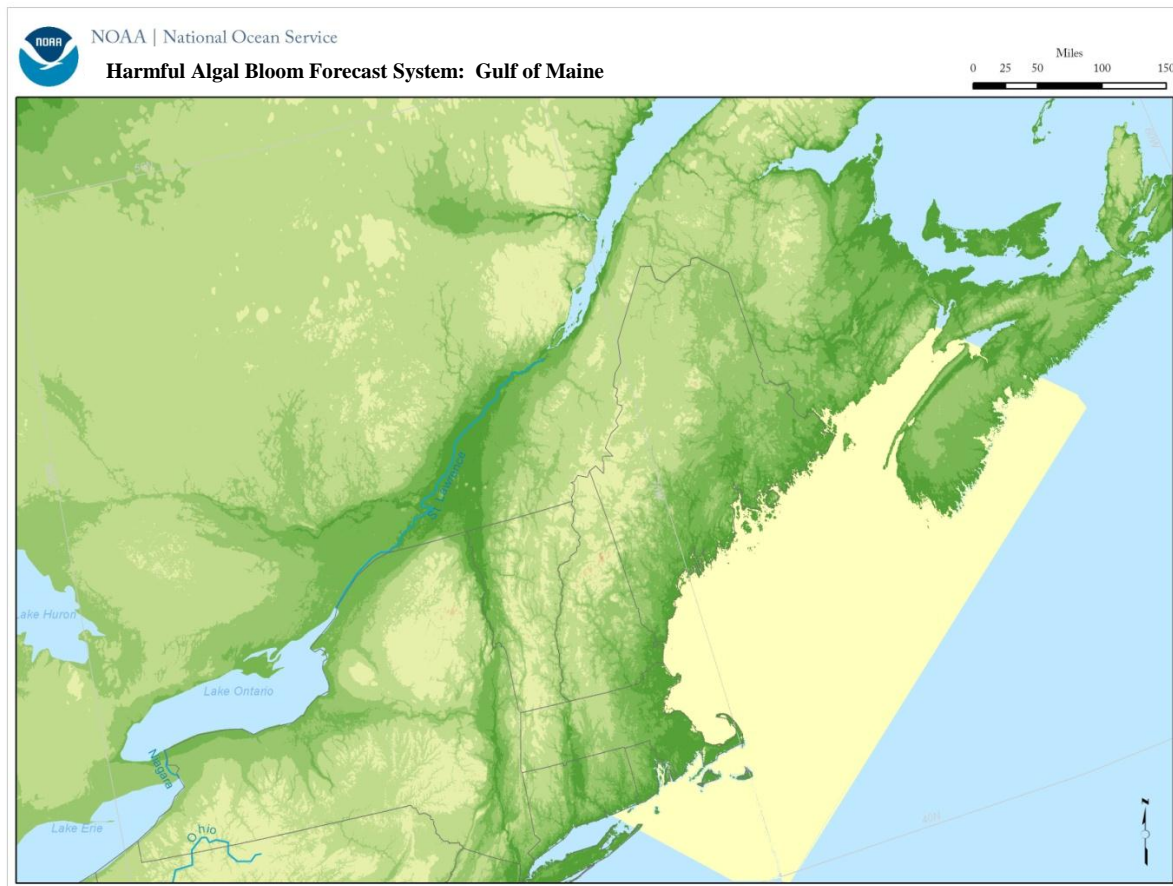

Figure 1. Delineation of the demonstration Gulf of Maine harmful algal bloom forecast region (shown in yellow).

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Methodology:

Seasonal HAB predictions are produced annually using an ensemble modeling approach and the fall cyst map from the previous year. Forcing of the ensemble members is based on previous years (starting in 2004), resulting in a prediction for the envelope of likely seasonal severity of the HAB. The seasonal prediction has been released by WHOI and NCSU as a press release prior to the onset of the bloom season.

Seasonal and weekly products are based on a coupled bio-physical model to simulate regional hydrodynamic conditions and *A. fundyense* bloom concentrations. The model consists of a ROMS based circulation module nested inside a global HYCOM model superimposed with tidal forcing, and an *A. fundyense* biological population dynamics module. Model output of the HAB field is generated and disseminated by North Carolina State University. Field observations are compared with model predictions to evaluate model skill.

Data Sources (The following data sources either support or supplement seasonal predictions and/or a coupled biological/physical circulation model developed by NCSU and WHOI):

- Tidal harmonic constituent data (ADCIRC)
- River runoff data (USGS)
- Remote sensing sea surface temperature data (NOAA CoastWatch)
- 6 hourly wind and heat fluxes from (NOAA/NCEP NOMADS; 35-km resolution)
- Monthly climatological nutrient fields (Bedford Institute of Oceanography and Univ. of ME)
- Solar radiation data (NOAA/NCEP)

- Historical and present in situ biological cyst maps
- Historical population dynamics data
- In situ data (NERACOOS, EcoMon, AZMP cruises, etc.)
- Shellfish toxicity data (ME DMR, NH DES, MA DMF)
- NWS meteorological observations and 14-day hydromet outlook

Data sources not currently incorporated into models, but of significance to future forecast products:
- *In situ* optical data from moored/motion sensors (ESP data reported by WHOI)
- Public and animal health data (from various sources including CDC, state labs and the community)

Outputs:
- Weekly modeled *Alexandrium fundyense* bloom intensity and location prediction
- Annual seasonal red tide severity prediction
- Model data comparisons using field observations

Management Action Supported by Forecasts:
- Provides guidance to coastal managers who regulate shellfish harvesting closures (Agencies: State and County Health Departments, etc.)
- Initiates *in situ* monitoring response by coastal managers (Agencies: MA Water Resources Authority (MWRA), ME Dept. of Marine Resources (DMR), NH Dept. of Environmental Services (DES), MA Division of Marine Fisheries (DMF), etc.)
- Seasonal prediction assists resource planning for annual monitoring efforts (see example agencies in previous bullet)
- Provides guidance to commercial shellfisheries for adjustment of harvest time/location prior to and during blooms
- Provides guidance to recreational shellfishermen for adjustment of harvest locations during blooms

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Primary Role of Local Partners, NOAA Partners and Managers in Forecasting and Validation:

Partner	Role in Forecasting
Local Partners:	
North Carolina State University (NCSU)	Development and demonstration of a coupled physical-biological *Alexandrium fundyense* model; Dissemination of weekly model predictions and model data comparisons
Woods Hole Oceanographic Institution	Scientific research and product development; Dissemination of annual seasonal prediction, Initial user needs and forecast requirements gathering, *In situ* sampling, Partnership building with state, county, and local managers
NOAA Partners:	
NOAA's National Centers for Coastal Ocean Science (NCCOS)	Initial user needs and forecast requirements gathering for product development; Partnership building with state, county, and local managers; Future role in forecast product evaluation, development of SOPs and training materials, product improvement and enhancement, and stakeholder needs assessments and evaluation.
National Weather Service (NWS)	Provider of weather model guidance, marine meteorological observations and hydromet outlook
Coastal and Resource Managers:	
Maine Dept. of Marine Resources (DMR), Massachusetts Dept. of Marine Fisheries (DMF), New Hampshire Dept. of Environmental Services (DES)	*In situ* sampling, toxin analysis and reporting; Provider of user requirements
Fisheries and Oceans Canada, Atlantic Zone Monitoring Program (AZMP), Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS), Ecosystem Monitoring Program (EcoMON-NOAA)	Providers of *in situ* coastal ocean observations and monitoring efforts

Forecast and Forecast Validation Limitations:

- Except during periods of active research programs (e.g. ECOHAB-GOM, GOMTOX), ad hoc *in situ* observations of water samples (including toxicity data) lack dense spatial and temporal coverage and are insufficient to enhance and improve the model predictions:
    - Limiting improvement of forecast quality and resolution
    - Hindering bloom validation
- No data assimilation used to correct model predictions
- HAB forecast accuracy relies upon the validity of oceanographic and meteorological model guidance (e.g. forecasted winds, currents, etc.).
- *A. fundyense* population dynamics model utilizes a seasonal nutrient climatology, and therefore does not account for interannual variability in nutrient availability.

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Current Sponsored Research to Inform the Gulf of Maine HAB Forecast System:

Program	Project	PIs	Institutions	Project Period
ECOHAB	GOMTOX: Observation and Modeling Studies on the Dynamics of *Alexandrium fundyense* Distributions in the Gulf of Maine	D. Anderson (lead), M. Bricelj, J. Deeds, S. Etheridge, S. Hall, B. Haskell, R. He, B. Kaefer, J. Manning, J. Martin, D. McGillicuddy, N. Pettigrew, C. Pilskaln, A. Thomas, D. Townsend, J. Turner	Woods Hole Oceanographic Institution (lead), Rutgers University, U.S. FDA, NOAA/NOS, North Carolina State University, NOAA/NMFS/NEFSC, Fisheries and Oceans Canada, University of Maine, University of Massachusetts	FY06-FY11
ECOHAB	Deposition and Resuspension of *Alexandrium fundyense* Resting Cysts in the Gulf of Maine	D. Anderson (lead), B. Butman, D. McGillicuddy, C. Pilskaln, R. Signell, A. Solow	WHOI (lead), USGS, University of Massachusetts	FY09-FY12
PCM	Implementation of an operational model for prediction of Alexandrium fundyense blooms in the Gulf of Maine	D. McGillicuddy (lead), R. He, D. Anderson	WHOI (lead), NCSU	FY12-FY15

Current Funding Sources for the Gulf of Maine HAB Forecast System:

NOAA

Recipients (by agency and primary role):

Federal Agencies:
EPA
FDA
NOAA

**State and Local Agencies,
Coastal and Resource Management,
Public Health:**
Maine Department of Marine Resources
Massachusetts Department of Public Health
Massachusetts Division of Marine Fisheries
Massachusetts Water Resources Authority
New Hampshire Department of
    Environmental Services
New York Department of Environmental
    Conservation
Rhode Island Department of
    Environmental Management
Town of Barnstable, Massachusetts
Town of Orleans, Massachusetts

Regional Associations:
Northeastern Regional Association of Coastal
    Ocean Observing Systems

HAB Research and Academia:
Battelle Labs
Fisheries and Oceans Canada
North Carolina State University
Rutgers University
University of Connecticut
University of Maine
University of Massachusetts, Dartmouth
University of New Hampshire
University of Rhode Island
Woods Hole Oceanographic Institution